The Chemical Basis of Life

I. Organic Chemistry

Most compounds that contain carbon are called organic compounds. This is because they come from living things. Examples of organic compounds are sugars, fats and proteins. Today, organic compounds can be made synthetically. Inorganic compounds such as salt and water generally do not contain the element carbon. The mineral carbon dioxide is inorganic.

A. The chemistry of carbon

1. Carbon has six electrons. Two electrons are found in the first energy level, and four are found in the second. Carbon can therefore share four electrons and thus form four covalent bonds.

2. Carbon can form single, double, or triple bonds.

B. Functional Groups

1. Functional groups are special groups of reactive atoms. These groups contain elements such as oxygen, nitrogen, sulfur, and phosphorous.

2. These groups are necessary for chemical reactions. Phosphate groups are involved in the formation of nucleic acids. Amine groups are involved in the formation of proteins.

C. Molecule building

1. Some organic compounds are small while others are large and can contain hundreds of thousands of atoms.

2. Building blocks of large molecules are called monomers. The monomers are linked by covalent bonds.

3. Molecules formed by linking two or more monomers are called polymers. Examples of polymers are large molecules such as starch, plastics and protein.

D. Two chemical reactions

1. Dehydration synthesis is the chemical reaction that forms the covalent bonds between the monomers making a polymer. During dehydration synthesis water is lost. One of the monomers loses a hydrogen atom while the other loses an –OH (hydroxyl) group. These two groups combine forming water and a covalent bond forms between the two monomers. An example of this process is the formation of starch from sugar.

2. Hydrolysis is the chemical reaction in which polymers are broken apart. Hydrolysis means “splitting by water”. A water molecule splits the polymer apart and the parts of the water molecule are added back to the monomers. When you digest starchy foods, hydrolysis splits the starch into the monomers glucose.

II. Carbohydrates

A. Carbohydrates are compounds made of carbon, hydrogen, and oxygen in a set ration (1:2:1). An example is glucose.

B. Sugars

1. Simple sugars are called monosaccharides. They have three, five, or six carbon atoms in the chain. Examples include glucose and fructose.

2. Disaccharides are sugars that made from two covalently bonded monosaccharides. The most common disaccharide is sucrose otherwise known as table sugar.

a. Sucrose made of one glucose and one fructose.

b. Lactose is made of one glucose and one galactose.

c. Maltose is composed of two glucose molecules and is found in seeds.

3. Polysaccharides are “multiple” sugars and can consist of thousands of bonded monosaccharides. They are used for fuel and energy storage.

a. Starch is used as food. Examples include corn, wheat, rice, and potatoes.

b. Plants use excess sugars to make starch.

c. Animals put their excess sugar into glycogen (this is stored in the muscles and the liver).

d. Plants produce cellulose for support of the plant.

e. Chitin is very strong and resistant. This is the outer covering of crustaceans and insects. This material also has value in our lives.

III. Lipids

A. Lipids are organic compounds that include fats, oils, waxes, and steroids. They do not dissolve in water.

B. Fats are composed of glycerol and three fatty acids. They are used for energy storage and insulation.

1. Carbohydrates can be converted to fats for more long-term storage.

2. Lipids contain twice as much energy per gram as carbohydrates and are therefore energy efficient.

C. Fat in animals is used as insulation from cold temperatures.

D. Phospholipids are a form of lipid that also contains the element phosphorous in the form of a phosphate. This type of lipid is important as the major component of the cell membrane as it helps to control the movement of materials into and out of the cell.

E. Steroids are lipids that are composed of four linked rings of carbon atoms.

1. Cholesterol is a steroid that is a major component of the cell membranes of animals.

2. Other examples of steroids include vitamin D (although modified) and hormones. A hormone is a special chemical that is produced in one part of the body but is used to control a function in another part of the body. Examples of steroid hormones include estrogen and progesterone, both of which control the menstrual cycle and are secreted by the ovaries.

F. Waxes are made of fatty acids and certain alcohols and coat objects making them waterproof

1. Leaves and fruit are coated with a wax to prevent the loss of water.

2. Water birds such as ducks spread waxy oil over their feathers to prevent the absorption of water.

3. We apply wax to automobiles to protect the finish. This wax is made from the Brazilian palm leaf wax.

G. Fats are formed by dehydration synthesis. One glycerol and three fatty acids are joined together in this process..

1. Fatty acids are made of a chain of carbon atoms with an acid group at one end. Three hydrogen are lost from the end of glycerol while one –OH group is lost from each fatty acid. These lost elements represent three molecules of water that is removed in this process.

H. If a fat has the maximum number of hydrogen attached to it, then it is called a saturated fat.

1. These fats have straight chains of carbon atoms.

2. Saturated fats are usually solids at room temperature.

I. Some fats have fatty acids that contain double bonds between the carbons.

1. The molecule is not saturated with hydrogen and is called an unsaturated fat.

2. If there is more than one double bond in the molecule, then it is called a polyunsaturated fat.

3. Unsaturated fats are generally liquids at room temperature.

J. A diet rich in saturated fats has been linked to the deposit of fat in the blood vessels which can lead to high blood pressure, stroke and heart disease.

IV. Proteins

A. Proteins are compounds that are composed of carbon, hydrogen, oxygen and nitrogen (sometimes sulfur).

1.Protein is very important.

a. Muscles are made of protein.

b. Hair is also made of protein and functions in protection of the body.

c. The flexibility and toughness of the skin is due to protein.

d. There are thousands of different kinds of proteins in the human body.

B. The structure of proteins

1. Proteins are polymers of amino acids. An amino acid is a compound that contains an amino group (-NH2), a carboxyl group (-COOH), and a side group.

2. The same 20 amino acids are used to make proteins. Ex. Amino acids are like letters that make up words. The words would symbolize a protein.

3. Through dehydration synthesis, a covalent bond forms between the amino group of one amino acid and the carboxyl group of another amino acid.

a. This bond is called a peptide bond.

b. The chains of amino acids hooked together by a peptide bond is called a polypeptide.

c. Examples include hemoglobin and enkephalins (these help in the perception of pain and pleasure).

d. The amino acid sequence is critical to the proper functioning of the protein. One change can have dramatic results.

i.e. One amino acid change in the protein hemoglobin causes the red blood cells to become deformed into a sickle shape. This disease is called sickle cell anemia.

C. Functions of proteins.

1. Movement

a. Actin and myosin proteins enable muscles to contract. This allows for the movement of the organism.

b. Collagen is the most abundant protein and forms bones, tendons, ligaments, and cartilage. It holds the body together and gives strength, flexibility and shape.

c. Keratin in various organisms makes hair, horns, and feathers.

d. Enzymes help control chemical reactions.

e. Hemoglobin carries oxygen in the bloodstream.

f. Casein stores amino acids in milk for use by the baby animal.

g. Many hormones are proteins. An example is insulin that helps control the amount of sugar in the bloodstream.

h. Antibodies are proteins that help defend the body by fighting off the invasion of viruses and bacteria.

D. Enzymes

1. Enzymes are special proteins that speed up the chemical reactions of the cell to a biologically useful rate.

2. An enzyme is a catalyst. A catalyst speeds up a reaction without being changed by the reaction.

3. A catalyst lowers the activation energy of the chemical reaction.

a. An enzyme works like a lock and key. A substrate is something that is to be acted upon. The enzyme will act upon the substrate.

b. The place where the substrate attaches and where the reaction takes place is found on the active site of the enzyme.

c. At the active site, the substrate is changed slightly by the enzyme so that a specific chemical bond is weakened.

d. Now that the bond is weakened, the reaction can proceed quickly.

e. The enzyme acts like a key that fits into the substrate (which acts like a lock). Only a specific key or enzyme will fit into the lock.

f. Enzymes are used by industry to make detergents, cheese, process food and chemicals and to detoxify waste.

V. Nucleic Acids

A. Nucleic acids are large complex molecules that are made of carbon, hydrogen, oxygen, nitrogen and phosphorus.

B. Nucleic acids contain the hereditary material of cells and are found in the nucleus therefore making them essential to life.

C. Nucleic acids are polymers made of the monomers of nucleotides.

1. A nucleotide is made of a 5-carbon sugar, a nitrogen-containing base, and a phosphate group.

a. AMP (adenosine monophosphate) is made of an adenine, ribose, and one phosphate.

b. ADP?

c. ATP?

2. Deoxyribonucleic acid (DNA) is an nucleic acid that has nucleotides that contain the sugar deoxyribose.

3. Ribonucleic acid (RNA) is a nucleic acid whose nucleotides contain the sugar ribose.

4. Because they have a structural difference, DNA and RNA also function differently.

a. DNA and RNA have different sugars.

b. DNA and RNA have different nitrogen-containing bases in their nucleotides. DNA has adenine (A), thymine (T), cytosine (C), and guanine (G). RNA has adenine (A), uracil (U), cytosine (C), and guanine (G).

c. DNA has two strands of nucleotides while RNA has only one strand. DNA looks like a spiral staircase with the sugar phosphate backbone as the edge of the staircase and the bases as the steps. This shape is called a double helix.

d. DNA carries the instructions that controls the cell’s activities (much like a blueprint). RNA take the instructions and manufactures the proteins for the cell.

e. The genetic information of the organism is found in the DNA of the cell and is passed onto the next generation.